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Title: Northstar Accelerator Based Mo99 Production Facility Design Support LANL FY20 Quarters 1 and 2 Facility Design Support Report

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Northstar Accelerator Based Mo99 Production Facility Design Support

LANL FY20 Quarters 1 and 2 Facility Design Support Report

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Summary

Facility design support this quarter centered on transfer of the target insertion and design details to MBraun and Springs, the companies under contract via Northstar to do the hot cell, target insertion and the local target shielding. A significant number of changes have been introduced by these vendors which have been reviewed and critiqued. In addition, the company contracted to produce the Mo100 disks announced that the tolerance on the thickness of 0.5 mm would be ±25%. An alternative design of the target holder was proposed. Bulk shielding and local target shielding design work has continued also and will be reported.

Target Holder and Assembly

To accommodate the high variability in disk thickness, a modified target holder was designed that would accommodate any disk thickness while holding the coolant gap thickness to 0.15 mm with very tight tolerance. In this design, the holder is made of 2 halves. Each half is filled with disks and the 2 halves are clam-shelled together. The disks are inserted with a proper spacing feature for coolant gap. As the 2 halves are brought together, the disks at the end of the halves, not in the target center, are back-to-back. The heat load at this location is low enough to accommodate this now double thick disk. Any minor space between these disks due to the variability in thicknesses can be taken up with steel shim. This is shown in Figure 1.

In the hot cell after irradiation, the 2 halves would be separated and the contents dumped into a tray. An electromagnet would be used to separate the ferromagnetic steel pieces, leaving behind the Mo for transfer to the extraction process equipment.

Currently, the plan is to proceed with a design developed by MBraun/Springs which incorporated a separation motion that in principle allows the disk to drop out of the holder while leaving the steel holder parts within the holder body. This is shown in Figure 2. As shown in the figure, this concept requires a rather thick yoke piece. The result is that the window is now some distance from the target housing. This has serious impact on several aspects of the design. First, there is a high heat load in the yoke itself and at present n means to remove that heat. Second, the window is cantilevered off of the housing, and then the cantilevered cylindrical part is bolted to the housing. There is 5 kW thermal in the flanges on each window (10 kW total) with no cooling. These are radical and very high risk changes to the baseline design. Thermal cycling of the flanges holding the window will certainly lead to helium leaks into the beamline. The wider target holder configuration also impacts the diameter of the target insertion pipe, increasing weight and adding complexity to the handling of the larger part. Radiation streaming control is also more difficult.

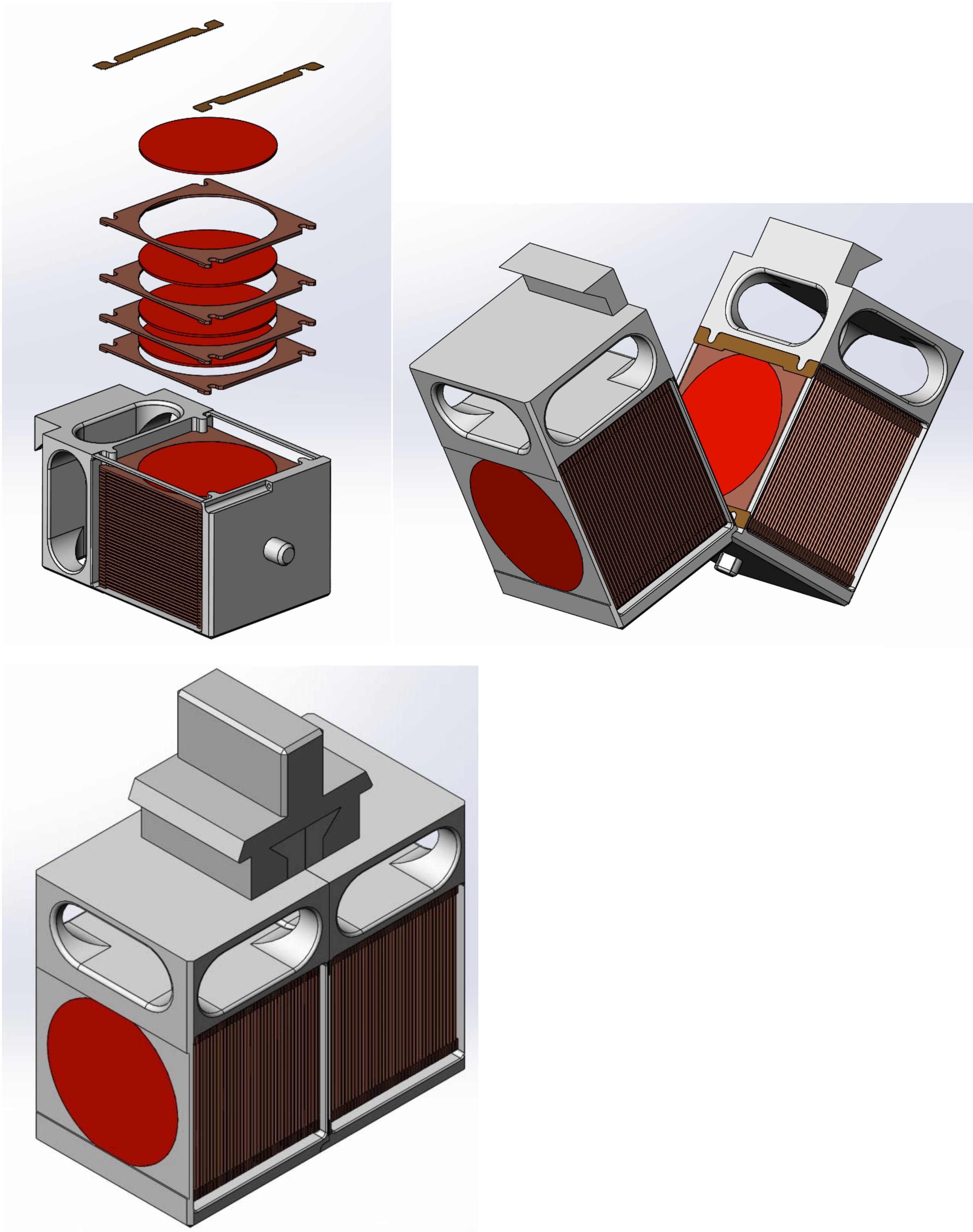


Figure 1. A target holder design which allows for a stack of disks of varying thickness to be inserted and removed.

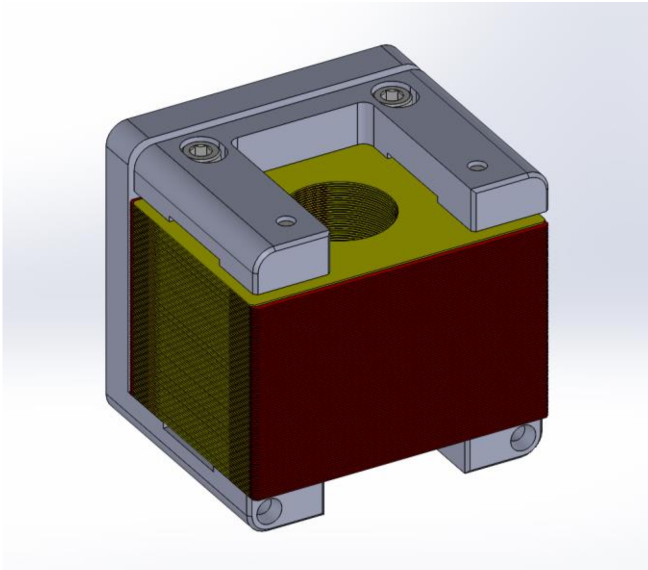


Figure 2. The current target design, also comprised of individual disk holders stacked in a body. In this design the U-shaped holder part can slide outward to open up the coolant gap and release the disks.

Bulk Shielding Analysis

Currently, shielding analysis is being done by LANL, ANL and Northstar, often overlapping or very similar models and assumptions. Work done by LANL will be summarized here, with no attempt at comparing and reconciling differences between results.

A “final” analysis of the complete assembly was done in October 2019. This layout is constructed with all HD concrete (4 g/cc). Local target shielding comprised of 2/1 steel and water mix is included. The model is shown in Figure 3. The resulting radiation dose from the target with full beam power is shown in Figure 4. There is the intent to be able to work on one rhodotron while the other is operating. The radiation in the rhodotron vaults under this scenario is shown in Figure 5. Figure 6 identifies the dose at important locations.

The beam heating at various points around the target was also analyzed. This is shown in Figure 7.

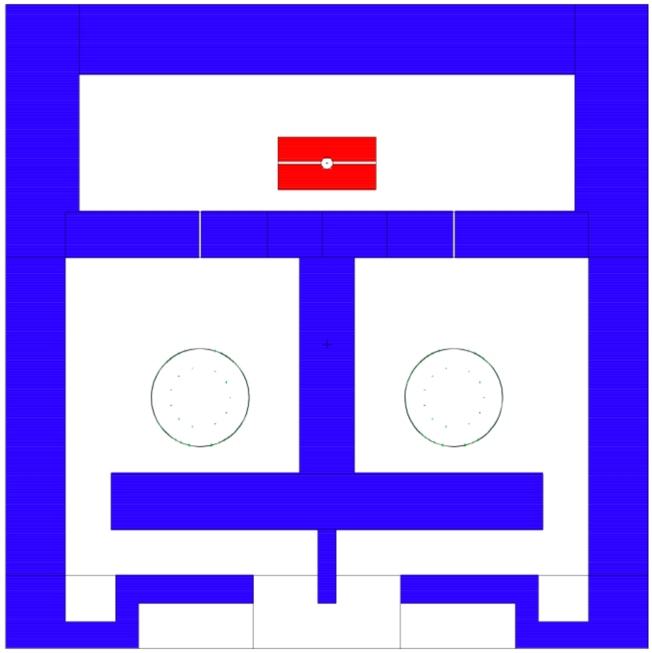


Figure 3. Latest (final) shielding model. Local target shielding is in red, the circles are the rhodotrons, bulk shielding in blue.

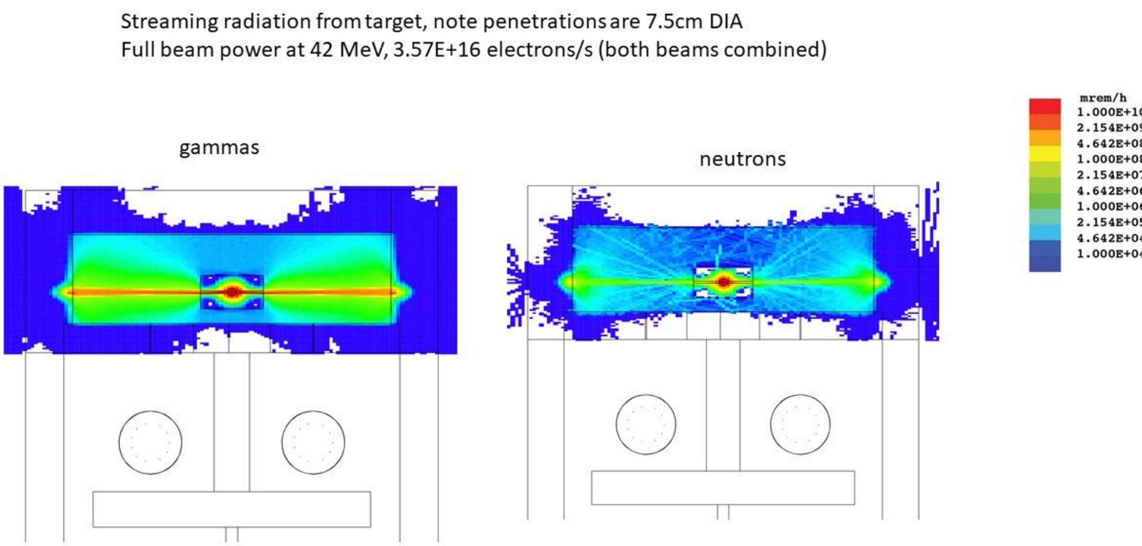


Figure 4.

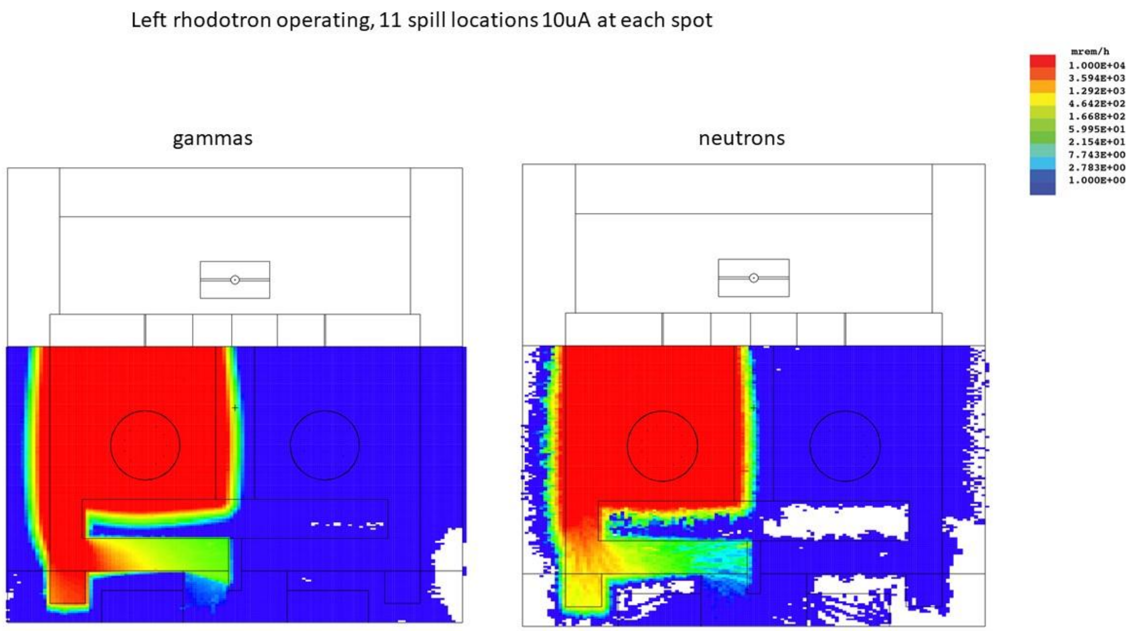
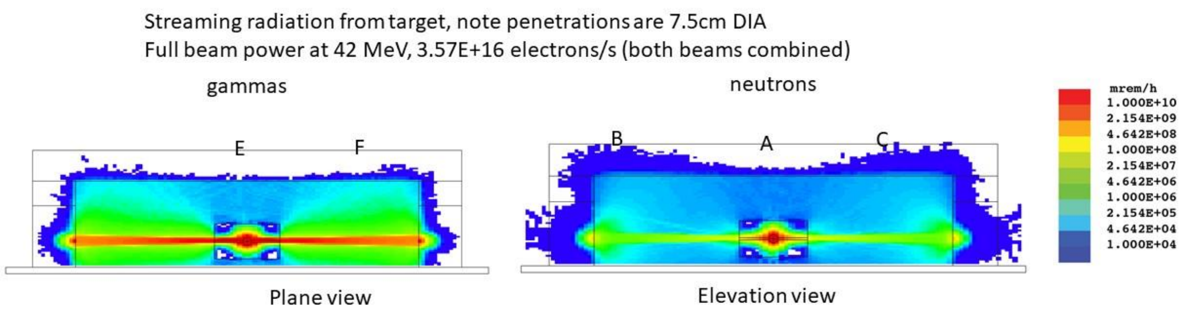
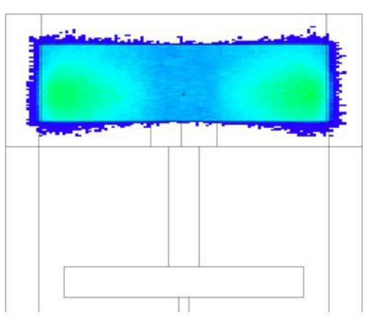


Figure 5.Dose rates in rhodotron vaults when one is not operating.





Location	Gammas mrem/h	Neutrons mrem/h
A	<0.1	<0.1
B	<0.1	<0.1
C	<0.1	<0.1
D	~1.0	<0.1
E	<0.1	<0.1
F	<0.1	<0.1

Relatively poor convergence

Figure 6. Dose rates at critical locations outside the shielding.

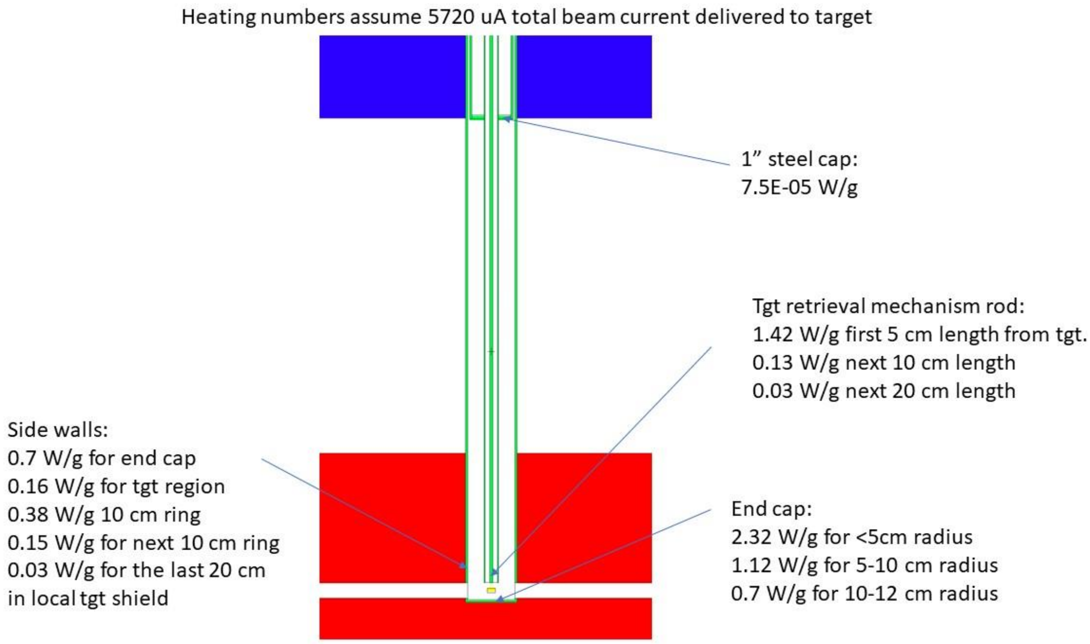


Figure 7. Beam heating in the regions around the target.

Local Target Shielding

LANL did preliminary local target shielding analysis and design last fiscal year. The suggested design was comprised of a relatively small number of steel boxes filled with steel bearings, 0.5 to 1” in diameter and cooled with water, resulting in a nominal 2/1 mix of steel and water. This design was based on information that there would be a 40 ton crane in the target chamber.

Since then Northstar has released the responsibility for that to a contractor, and the crane capacity has been established at 6 tons. This has resulted in a large number of smaller boxes filled with the steel bearings. This is shown in Figure 8.

LANL has advised to not interlock the boxes. Radiation shine paths perpendicular to the beam are of secondary importance, and the narrow gap between boxes can be filled with lead or steel wool or matting.

More important however, is that the large number of boxes, and the vertical stacking, makes the water cooling rather complex. LANL suggestion is to install larger boxes with a flow distribution baffle at the bottom, then place steel plates vertically, with gaps between for cooling. Water would flow from bottom to top, also improving the removal of any gases generated by radiolysis. This would introduce radiation streaming paths normal to the beam. This could be accommodated, if necessary, by additional bulk shielding at the wall.

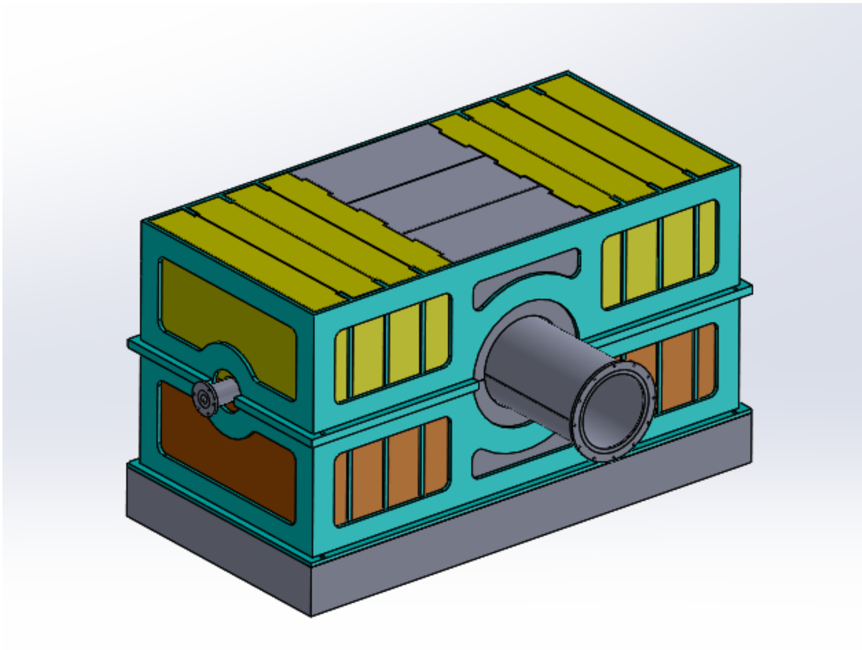


Figure 8. Current conception of the local target shielding, contractor design.

Near Target Design Details

As the contractor progresses on the target insertion and handling scheme, specific details become the focus of review and attention. In these cases either Northstar askes for review and comment or LANL identifies an item of concern and initiates discussion. A few important examples of this are sited here.

Figure 9 shows a cross section view of the target, with beam pips entering from the top and bottom. The current design has the windows screwed to the housing rather than welded. This will be difficult or impossible to adequately cool. Thermal cycling in this region will loosen the bolts over time. The windows should be welded to the housing and the bolted joint moved away from the high beam energy region directly in line with the target. If the bolted on window remains the preferred solution, the inner flange piece, currently envisioned as welded on, should be a machined feature of the housing, significantly improving thermal contact and facilitating cooling. As stated above, there is a very high heat load in the yoke and the target flanges that as yet has no cooling

Also in Figure 9, the target insertion mechanism remains in close proximity to the target during irradiation. Also, the containment pipe is in vacuum. Helium is flowing through the target and therefor fills the target insertion pipe. Some small fraction of the total helium flow should be directed down the target insertion pipe for cooling of these components.

The target cross section view through the helium cooling lines, as currently conceived, is shown in Figure 10. The primary concern here is the rapid transition from round pipe to the rectangular flow channel necessary for flow through the target. This will result in unnecessary pressure drop, and a very turbulent flow entering the target, with regions of flow separation and recirculation. The recommendation is to extend the rectangular section of pipe around the bend and to make a smoother transition from the round to rectangular. Also, the helium pipe diameter has been increased from 2” to

3”. While this reduces pressure drop along the long run from and back to the blower, it requires a larger target insertion pipe and requires more difficult or space consuming radiation shine path reduction.

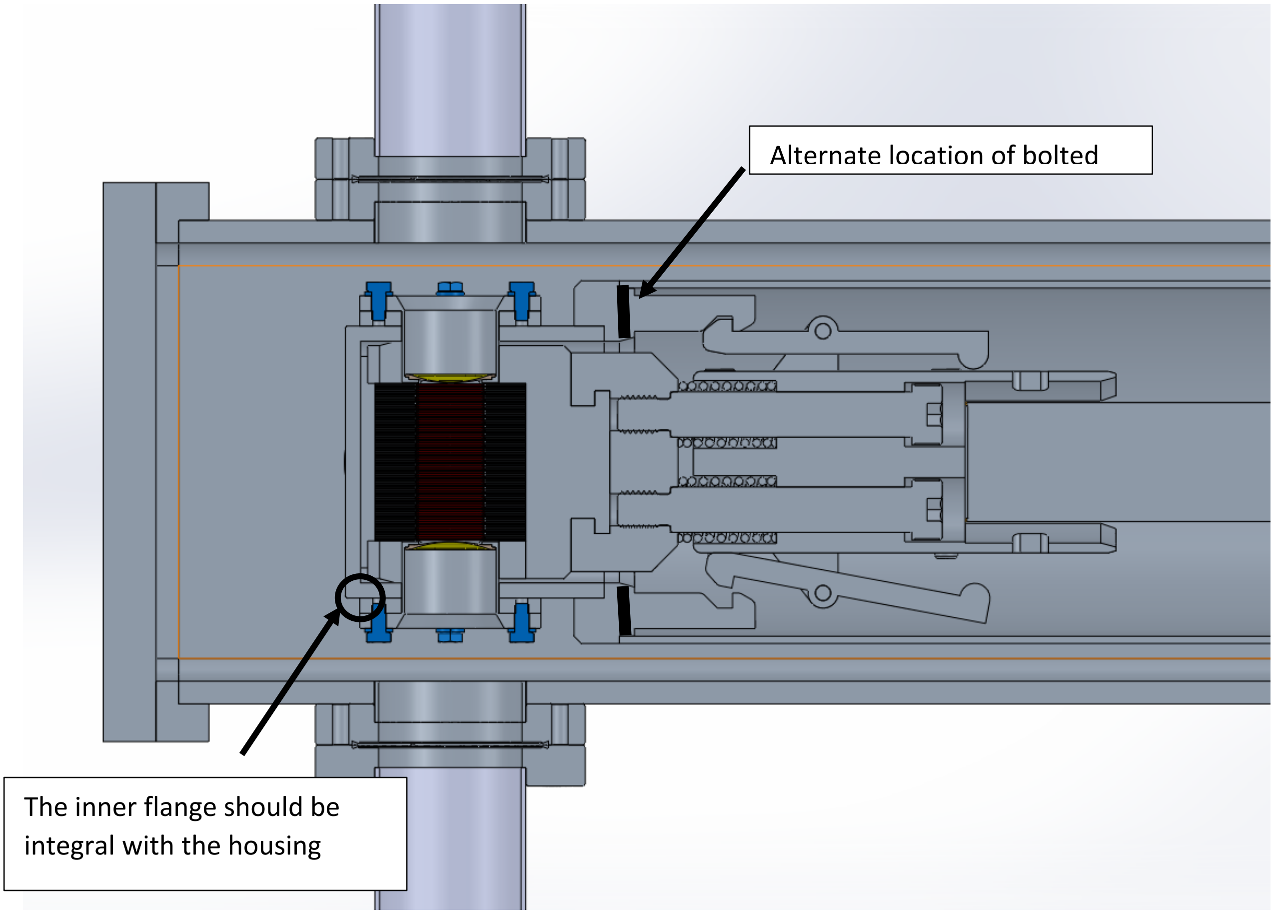


Figure 9. Cross section view of the target, as currently configured, with window bolted on to the housing.

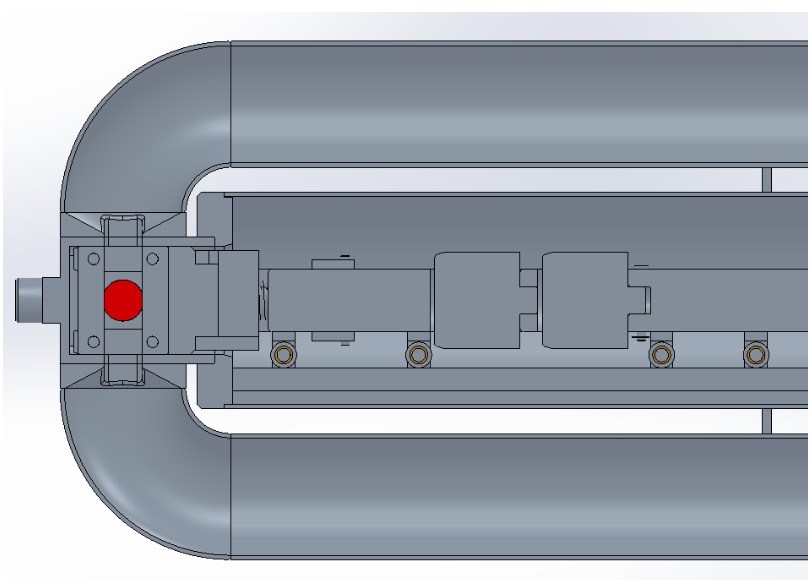


Figure 10. Cross section view of the target through the helium supply route.

Northstar proposed a variation on the rectangular elbow that includes a gradual transition to the round pipe. This is shown in Figure 11. These variations have so far not been incorporated into the design.

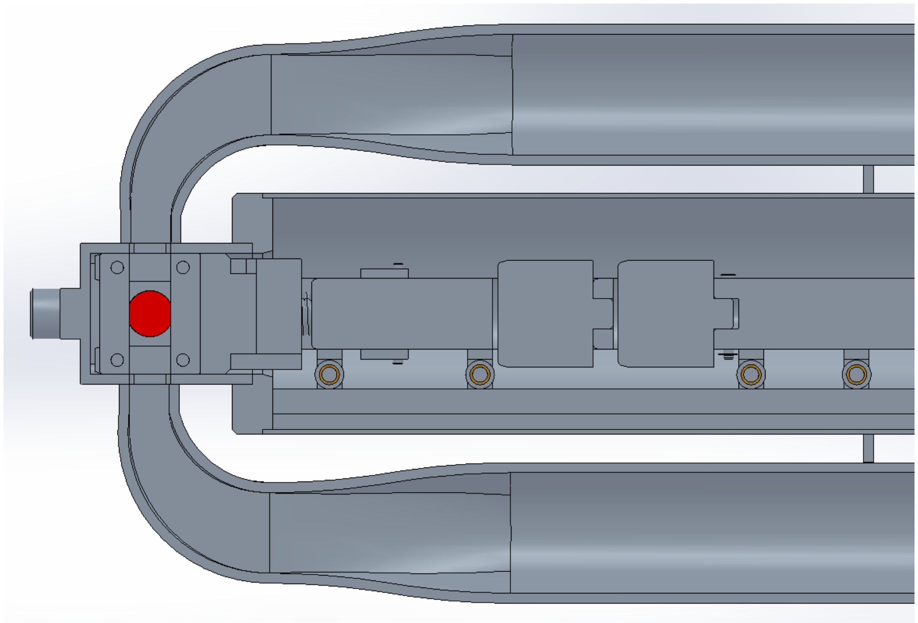


Figure 11. Improved design of the helium channel entrance to and exit from the target.

Target Insertion and Removal

A scheme for target and insertion and removal has been developed by the prime contractor. This is comprised in the main of a piece that holds the target and target holder and a pusher that moves along a rail using a chain drive to lock the target into place, then unlock after irradiation to retrieve the target. Shielding cylinders made up of stacked steel and poly are slid into the target insertion pipe as well. The hot cell design is quite evolved, with capacity to handle the Mo disks and place in a cask, handle the shielding cylinders, store hot target holders, etc.

The system is complex, but all elements and components are necessary. The overall configuration is in principle workable and commendable. Mock-up and testing as much as possible is necessary. The possibility of an operational failure that requires removing the insertion pipe must be minimized. The design does have a process for removing and replacing the target insertion pipe in this case or in the event of a window failure. The insertion pipe is nominally 20’ long. The pipe has a bolted flange half way down to reduce the length that needs handing. The segments will be moved to a storage area for rad dose decay.

One suggestion to reduce the amount of material in the hot cell is to remove the target holders after each run using a drop to a separate cask and storing these pieces in a decay cell.

LANL will continue to work with Northstar and the contractors to refine and test this system over the months ahead.

Summary

Northstar is rapidly advancing their accelerator based Mo99 production facility design. Key areas of progress are the completion or near-completion of the bulk shielding design, target holder design, target insertion and removal system design, hot cell design and the local target shielding. Nonetheless, most of this remains a work in progress, requiring critique, design evolution, full analysis including pressure code compliance validation and testing or mock-up demonstration. There have been major design decisions that introduce significant risk, primarily in the near-target region. The contractor has introduced a yoke piece which forms now the outer ends of the target holder. These add significant mass without adequate cooling. The window some distance from the housing. The purpose of the yoke is to simplify the Mo target from the holder, but introduces high risk to failure. The windows are designed to last the lifetime of the facility. Instead of welding the windows to the housing, the window is now some distance away, suspended on a cylindrical extension that is bolted on to the housing, creating a problem where none existed before. Without adding significantly more complexity to supply cooling to new components and construction, the risk of failure is extremely high.